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TERRESTRIAL ISOPODS AS BIOLOGICAL INDICATORS OF ZINC POLLUTION IN THE READING AREA, SOUTH EAST ENGLAND *

S.P. HOPKIN, C.A.C. HAMES and S. BRAGG

Department of Pure and Applied Zoology, University of Reading, Whiteknights

Over the last decade, it has been increasingly recognised that levels of pollutants in abiotic samples such as soil, air and water are not good indicators of the potential effects of environmental contaminants on organisms. In sites contaminated with metals, the suggestion has been made in numerous publications that concentrations in «indicator» species of invertebrates provide a more accurate parameter for measuring the «bio-availability» of these pollutants (MARTIN & COUGHTREY, 1982). In a review on the use of terrestrial invertebrates as biological indicators of pollution, HOPKIN et al. (1986) concluded that isopods were the ideal organisms for this purpose because they have a strong affinity for metals and are common in urban and rural habitats. Their study on zinc, cadmium, lead and copper pollution from a smelting works in the Avonmouth area, south-west England, showed that the areas identified as being «contaminated» were broadly similar for woodlice, leaf litter and soil but that concentrations of metals in *Porcellio scaber* could not be accurately predicted from levels in these samples at individual sites.

The source of zinc, cadmium, lead and copper pollution in the Avonmouth area could be clearly identified on maps prepared from concentrations of metals in soil and woodlice collected from sites 5 km apart within the region (HOPKIN et al., 1986), because the smelting works is such a major source of aerial contamination (COY, 1984). However, a distance of 5 km between sampling sites may be too great if more localised sources of metal pollution are to be detected. In the telephone directory for the Reading area, several industrial concerns are listed which are potential sources of metal contamination because they use zinc, cadmium,

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lead and copper in processes such as galvanising, electroplating and secondary smelting. The study described in this paper set out to determine whether these industries were contaminating soil and two species of isopods in the Reading area and if so, how close together sampling sites had to be to identify the source of pollution.

MATERIALS AND METHODS

Collection and analysis of samples

About 20 specimens of *Porcellio scaber* Latreille, 1804 and *Oniscus asellus* Linné, 1758 and a representative sample of surface soil to a depth of 2 cm (50 g) were collected over a 3 day period from 36 sites around Reading in September 1985 (Fig. 1). Sites were selected by driving to the centre of 5 × 5 km squares marked on a 1:50000 Ordnance Survey map and choosing the nearest suitable habitat in which isopods could be expected to occur. Further samples of woodlice and soil were collected from

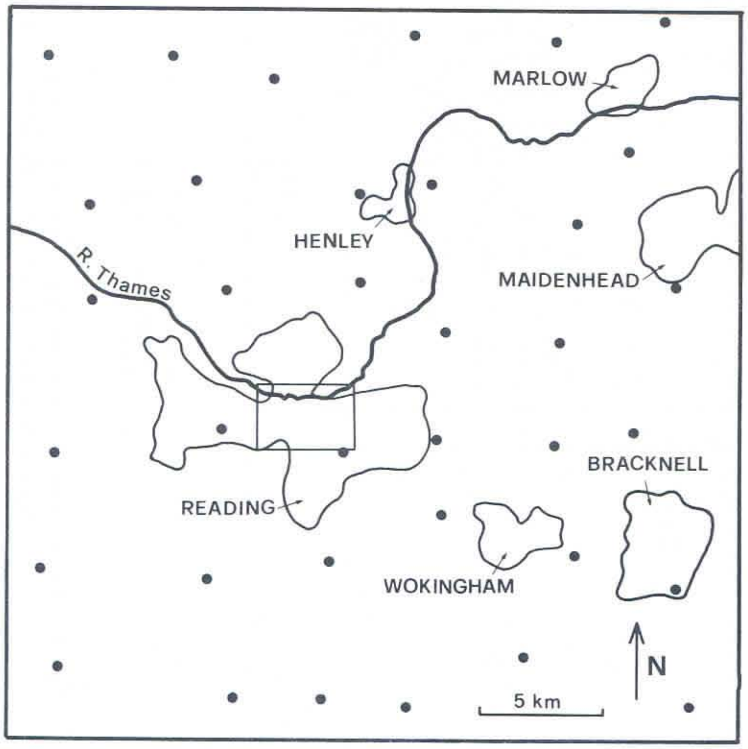

Fig. 1. — Sites in the Reading area from which samples of soil, *Porcellio scaber* and *Oniscus asellus* were collected (●).

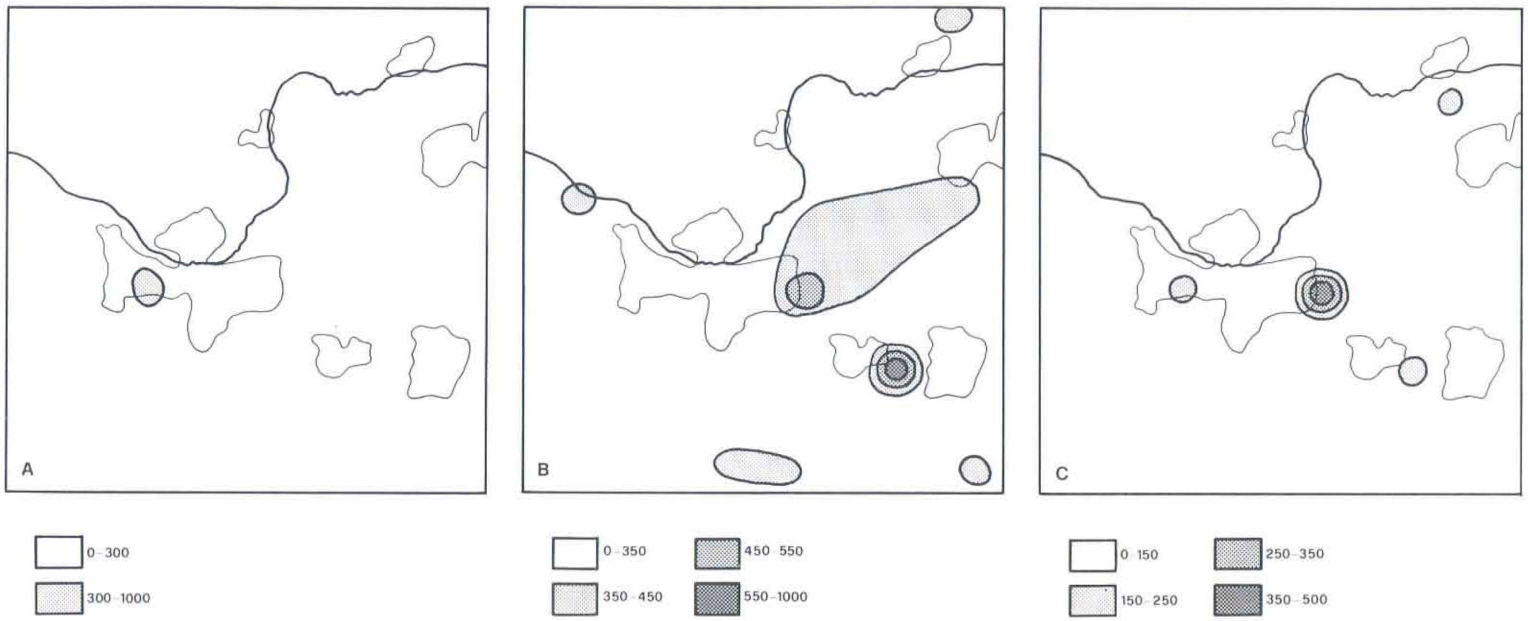

Fig. 2. — Regional distribution of concentrations of zinc (µg g^{-1} dry weight) in soil (A), *Porcellio scaber* (B) and *Oniscus asellus* (C) in the Reading area based on data from the 36 sites shown in Fig. 1.

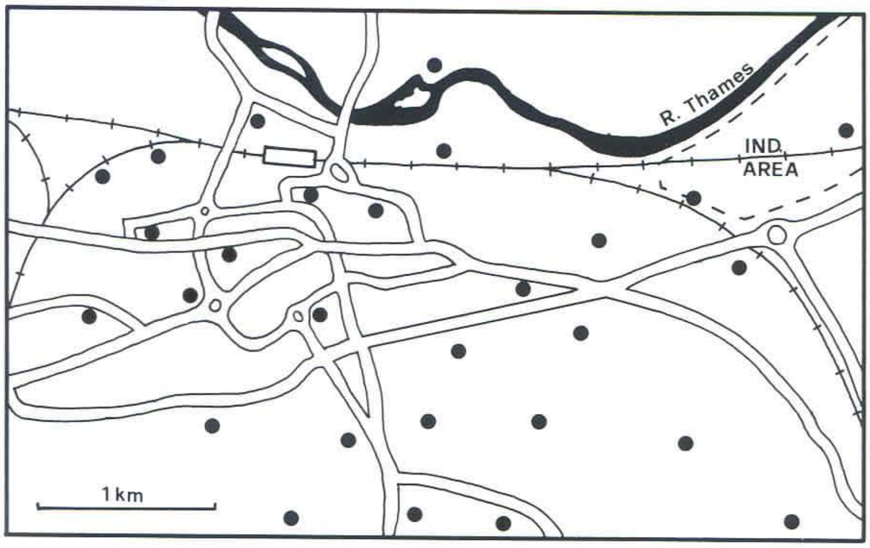

Fig. 3. — Sites in central Reading from which samples of soil, *Porcellio scaber* and *Oniscus asellus* were collected (●). The industrial area contains several factories which use zinc in their manufacturing processes.

27 sites approximately 0.5 km apart in central Reading over a 2 day period in October 1985 (Fig. 3). Leaf litter was not collected because there was none present in most of the urban sites. Samples were stored in polythene bags in a deep freeze until analysis.

Woodlice and soil were dried overnight at 70 °C. The 12 largest specimens of *P. scaber* and *O. asellus* from each site were pooled in pairs of flasks and digested in 20 ml of boiling, concentrated Aristar grade nitric acid (BDH Chemicals, Poole, Dorset, UK). The digests were diluted to 100 ml with double-distilled water. A sample of soil (1 g) from each site was prepared in a similar manner. The digests were analysed for zinc, cadmium, lead and copper by flame (Varian Spectra 30) or flameless (Varian GTA96) atomic absorption spectometry. National Bureau of Standards (Gaithersburg, USA) reference materials of bovine liver (SRM 1577a) and tomato leaves (SRM 1573), and National Research Council of Canada (Ottawa, Canada) reference material of lobster hepatopancreas (TORT-1) prepared in the same manner, gave derived concentrations of zinc, cadmium, lead and copper which were within 10% of the certified values.

Preparation of maps and graphs

Maps were prepared showing the regional distribution of concentrations of zinc in the two species of woodlice and soil from the Reading area based on data collected from sites 5 km apart (Fig. 2A-C), and from Reading town centre based on data collected from sites approximately 0.5 km apart (Fig. 4A-C). Maps were also prepared showing the regional distribution of concentrations of cadmium, lead and copper in the same samples but these did not reveal such distinct sources of contamination and

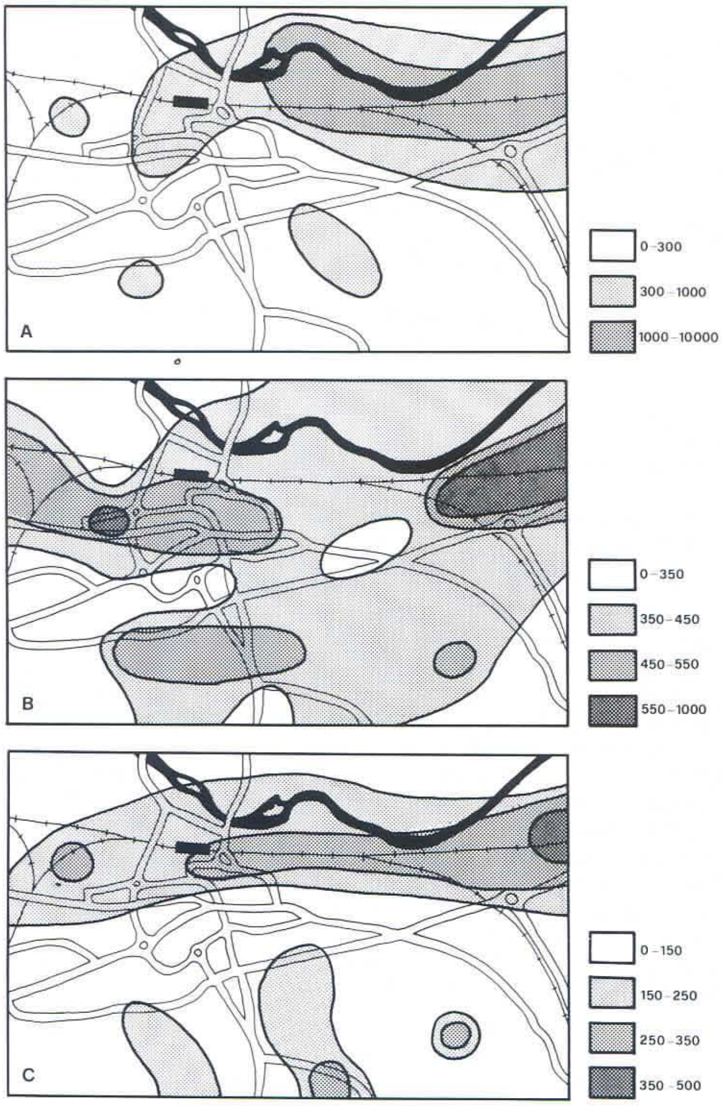

Fig. 4. — Distribution of concentrations of zinc (μg g^{-1} dry weight) in soil (A), *Porcellio scaber* (B) and *Oniscus asellus* (C) in central Reading based on data from the 27 sites shown in Fig. 3. The main sites of moderate to heavy zinc contamination of soil and isopods are close to the industrial area.

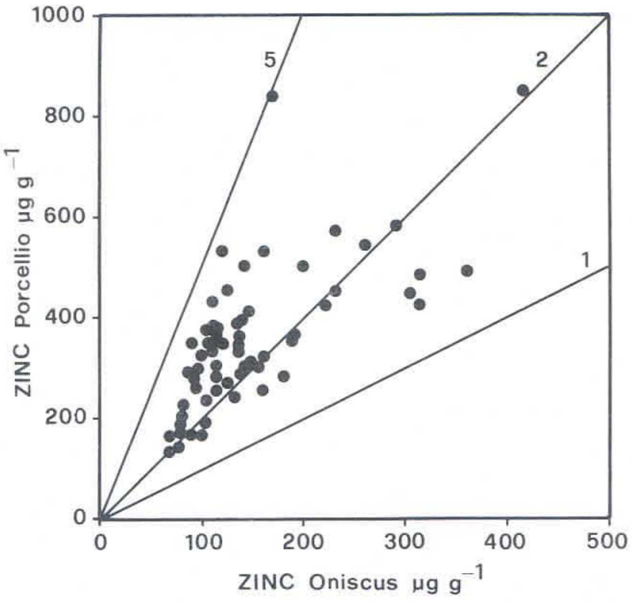

Fig. 5. — Scatter diagram relating concentrations of zinc in the two species of isopods at the 63 sampling sites in the Reading area (dry weight). The lines on the graph join points with the same concentration factor.

are not reported in this paper. Lines were drawn by eye delimiting levels of contamination in *P. scaber* and soil proposed by HOPKIN et al. (1986). Corresponding levels of contamination in *O. asellus* (Table 1), were estimated from the ratio of zinc concentrations to those in *P. scaber* from all 63 sites (Fig. 5).

Scatter diagrams were drawn of logarithmically-transformed values of zinc concentrations in *P. scaber* against soil, and *O. asellus* against soil from all 63 sites in the Reading area (Fig. 6). For comparison, a similar diagram was also drawn of zinc

Table 1.

Ranges of concentrations which delimit the five «levels of contamination» of zinc in pooled samples of 12 specimens of Porcellio scaber, Oniscus asellus *and soil* ($\mu g\ g^{-1}$ *dry weight; based on* HOPKIN *et al., 1986).*

Level of contamination	*P. scaber*	*O. asellus*	Soil
Uncontaminated	0- 350	0-150	0- 300
Low contamination	350- 450	150-250	300- 1000
Moderate contamination	450- 550	250-350	1000-10000
High contamination	550-1000	350-500	10000-50000
Very high contamination	>1000	>500	>50000

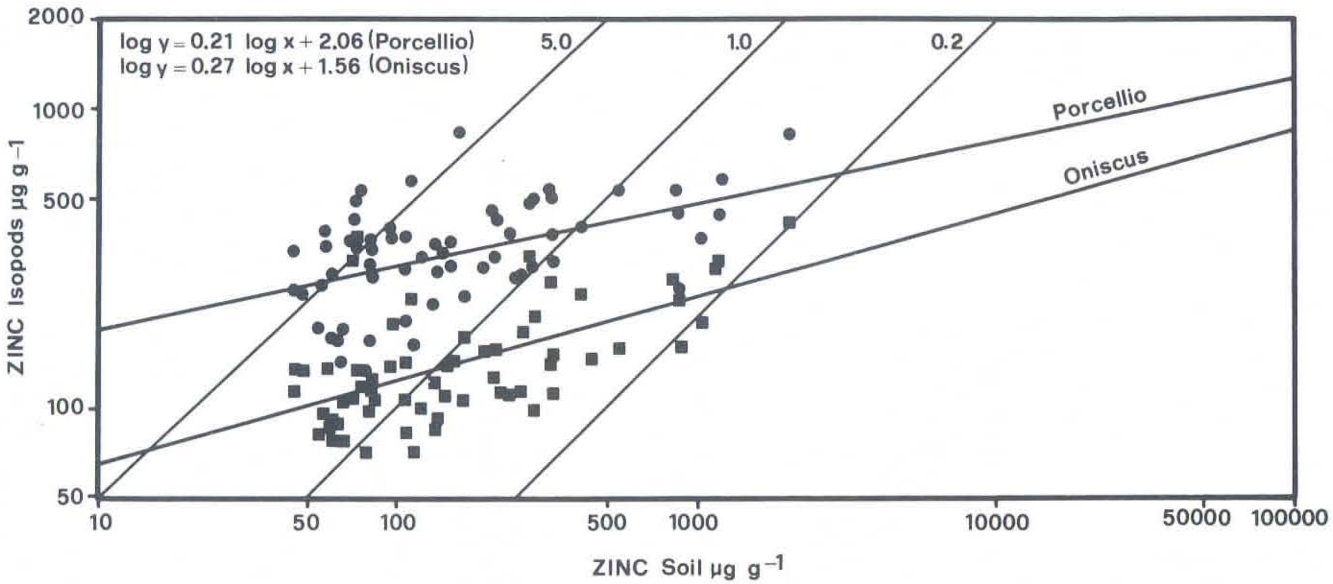

Fig. 6. — Scatter diagram relating concentrations of zinc in two species of isopods to concentrations in soil at the 63 sampling sites in the Reading area (dry weight). Regression lines through the points for *Porcellio scaber* (●, $r = 0.50$) and *Oniscus asellus* (■, $r = 0.59$) are statistically significant ($P < 0.001$). Three lines are also drawn on the graph which join points with concentration factors of 0.2, 1.0 and 5.0.

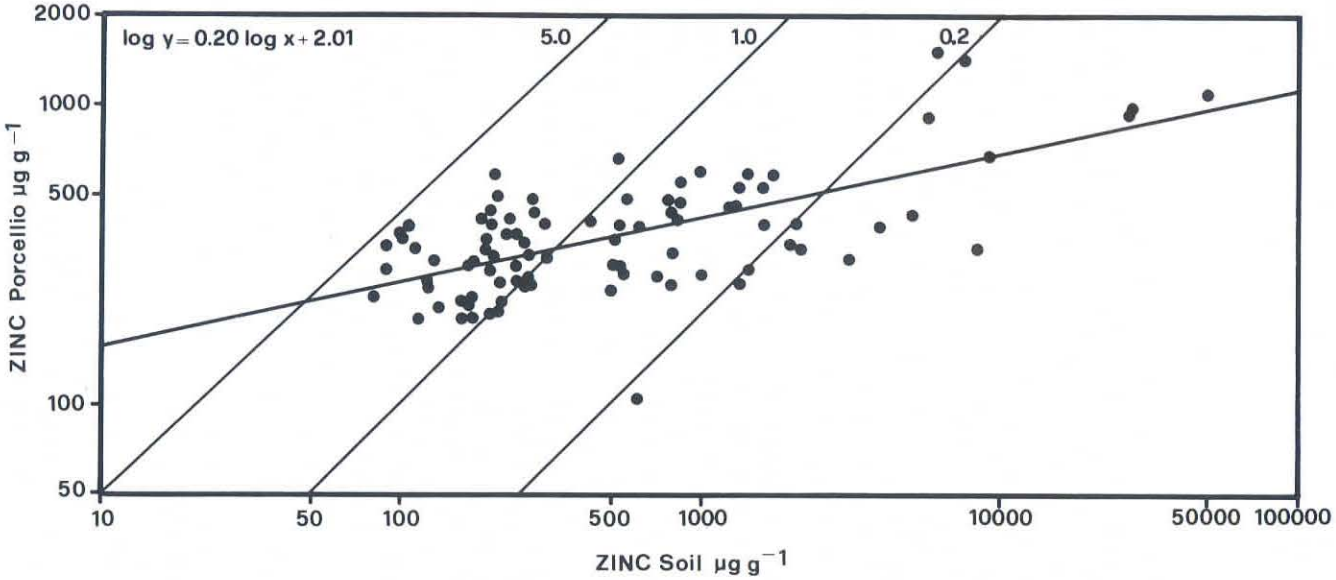

Fig. 7. — Scatter diagram relating concentrations of zinc in *Porcellio scaber* to concentrations in soil at 89 sites in the Avonmouth area (dry weight, data from Hopkin et al., 1986). The regression line through the points ($r = 0.64$) is statistically significant ($P < 0.001$). Three lines are also drawn on the graph which join points with concentration factors of 0.2, 1.0 and 5.0.

concentrations in *P. scaber* against soil from 89 sites in the Avonmouth area (Fig. 7, from data of Hopkin et al., 1986) which has not previously been presented in this form.

RESULTS

The 30 × 30 km area centred on Reading contains no major source of regional zinc pollution of the soil. Only one site was in the low contamination category (Fig. 2A). The maps of the same area for woodlice show that there are isolated sites at which zinc concentrations are above the uncontaminated level, in particular the site between Wokingham and Bracknell, and the site on the eastern edge of Reading (Fig. 2B, C). The woodlice at these sites were collected from discarded household refuse which had presumably contaminated the food of the woodlice with zinc. There is however a suggestion of an aerial source of zinc contamination in east Reading as the concentrations in *Porcellio scaber* decrease away from the town in the direction of the prevailing wind which blows from the south-west (Fig. 2B).

Within Reading, there is clear evidence that soil and isopods in some areas of the town centre are moderately to heavily contaminated with zinc. The map of the geographical distribution of zinc concentrations in the soil (Fig. 4A), shows that the highest levels occur in the north-eastern part of the area in a strip running westwards from the main industrial site. Isopods from within the area where the soil is moderately contaminated are moderately to heavily contaminated with zinc (Fig. 4B, C). However, there are several other sites where woodlice contain much higher levels of zinc than would be predicted from a comparison with soil concentrations.

The pooled sample of 12 *P. scaber* contained more than twice the concentration of zinc than *Oniscus asellus* in most sites (Fig. 5) and the scatter plots of concentrations of zinc in the isopods against concentrations in the soil, show the points for the two species to be clearly separated (Fig. 6). The slope of the lines of best fit are much less than one for both species. Consequently, the concentration factor for zinc (concentration in woodlice/concentration in soil) decreases as the level of contamination of the soil increases (Fig. 6). The equation which describes the line of best fit of concentrations of zinc in *P. scaber* against soil in the Reading area (Fig. 6) is almost identical to that of similar samples collected from 89 sites in the Avonmouth area (Fig. 7).

There are several sites in the Reading area (Fig. 6) where the soil contains much lower concentrations of zinc than the least contaminated sites around Avonmouth (Fig. 7). This suggests that even in areas remote from the Avonmouth smelting works, the soil has been enriched from long-distance aerial fallout of zinc.

DISCUSSION

There are numerous potential sources of environmental metal contamination in urban areas. The detection of such sources by the analysis of concentrations of metals in soil and the biota depends on the type and extent of pollution, and the distance between sampling sites. This study has shown that the zinc contamination of soil and isopods resulting from industrial activity in central Reading was not apparent when samples were collected at 5 km intervals (Fig. 2A-C), but showed up clearly in maps prepared from data collected at intervals of 0.5 km (Fig. 4A-C). A study is currently being carried out to try and identify the source(s) of the zinc contamination by sampling soil and isopods at 50 m intervals in an area centred on the main industrial site.

On an area basis where data from several sites is plotted onto a map, major regional sources of metal pollution can be localised from analysis of soil samples (HOPKIN et al., 1986). The similarity between the parameters of the regression lines of concentrations of zinc in *Porcellio scaber* and soil in the Reading (Fig. 6) and Avonmouth areas (Fig. 7) suggests that this relationship is probably applicable in most regions. However, although it would be possible to estimate the concentrations of zinc in populations of *P. scaber* using this relationship, there is such a large scatter of points around the lines that most estimates for individual sites would be very inaccurate. The extent of zinc contamination of the soil at a site is therefore not a good guide to the «availability» of the metal to isopods, and probably other species of terrestrial invertebrates as well (MARTIN & COUGHTREY, 1982).

Pooled samples of *P. scaber* always contained a greater concentration of zinc than *Oniscus asellus* at each site (Fig. 5), an observation which has been reported in previous papers (JOOSSE & VAN VLIET, 1984; HOPKIN et al., 1985). When the two species are reared on identical diets in the laboratory, they exhibit the same difference in their zinc concentrations (HOPKIN, unpublished results). This must therefore be due to differences in the digestive physiology of *P. scaber* and *O. asellus* rather than to choice of foods differing in zinc content. The ratio between concentrations of zinc in *P. sc* [illegible] least contaminated sites was between about two and four (Fig. 5) but at moderately contaminated sites this ratio was distinctly lower. Further collections of both species from heavily contaminated sites are required to determine whether this trend is significant.

A «suite of indicator species» has been developed for monitoring metal contamination in marine ecosystems (BRYAN et al., 1985). In the

terrestrial environment, biological monitoring is still at an early stage of development. Further research is required on the relationships of metal concentrations between species of invertebrates in a wide range of sites before a similar «suite» of organisms can be chosen for monitoring the environmental impact of metal pollution in terrestrial ecosystems. The study described in this paper support the inclusion of terrestrial isopods in such a group.

SUMMARY

The concentrations of zinc were determined in samples of soil, and whole specimens of the woodlice *Porcellio scaber* Latreille, 1804 and *Oniscus asellus* Linné, 1758, collected from 63 sites within an area of 30 × 30 km centred on Reading, South East England. Two sets of maps were drawn to compare the geographic distribution of concentrations of zinc in soil and woodlice in the whole sampling area based on data from 36 sites spaced at 5 km intervals, and in Reading town centre compiled from data from the remaining 27 sites spaced at intervals of about 0.5 km.

No major regional source of zinc pollution could be identified on maps prepared from concentrations of this metal in soil or woodlice samples collected 5 km apart. However, maps of zinc concentrations in soil and woodlice collected 0.5 km apart in Reading highlighted several sites which could be regarded as being «contaminated» with this metal. Most of these sites were within a few kilometres of the main industrial area where several factories are located which use zinc in their manufacturing processes.

The concentrations of zinc in *P. scaber* were about twice those of *O. asellus* at each site. This stressed the importance of accurate identification of species in biological indicator studies. The correlation coefficients between the concentrations of zinc in both species of woodlice and soil were positive and statistically significant ($P < 0.001$). At individual sites, however, the concentrations of zinc could not have been predicted accurately from the levels in soil due to the large scatter of data points along the lines of «best fit».

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Address of the first author: Dr. STEPHEN P. HOPKIN, Department of Pure and Applied Zoology, University of Reading, P.O. Box 228, Whiteknights, Reading RG6 2AJ (United Kingdom).